TRIUMF

Canada's National Laboratory for Particle and Nuclear Physics
Laboratoire national canadien pour la recherche en physique nucléaire
et en physique des particules

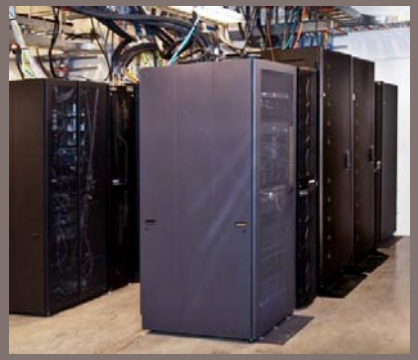
Report from TRIUMF

June 16, 2014

Probing the structure and origins of matter

Advancing isotopes for science and medicine

Reiner Kruecken | Science Division Head | TRIUMF
Professor of Physics | University of British Columbia

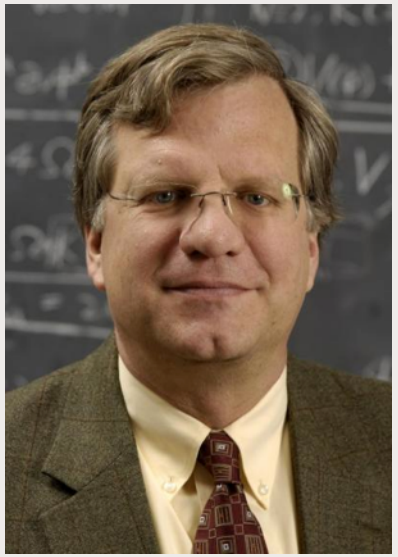


Owned and operated as a joint venture by a consortium of Canadian universities via a contribution through the National Research Council Canada
Propriété d'un consortium d'universités canadiennes, géré en co-entreprise à partir d'une contribution administrée par le Conseil national de recherches Canada

Incoming TRIUMF Director - July 2014

Dr. Jonathan Bagger, Johns Hopkins University

- Krieger-Eisenhower Professor
- Vice Provost, Interim Provost
- Department Chair



- Ph.D. Princeton 1983
- Postdoc, Stanford Linear Accelerator Center
- Associate Professor, Harvard University

- Member of the Institute for Advanced Study
- Chair of the ILC Steering Committee
- Vice chair US HEPAP
- Fellow APS, AAAS
- Fermilab Board of Overseers
- SLAC Scientific Policy Committee
- Space Telescope Institute Council
- Board of Directors of the National Space Biomedical Research Institute

TRIUMF: A National Science Laboratory

Members

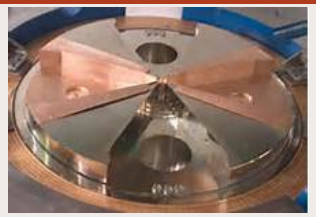
University of Alberta
University of BC
University of Calgary
Carleton University
University of Guelph
University of Manitoba
Université de Montréal
Queen's University
Simon Fraser University
University of Toronto
University of Victoria
York University

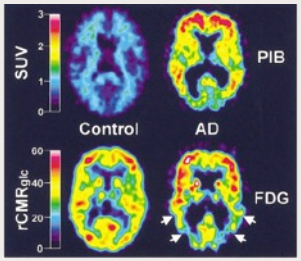
Associate Members

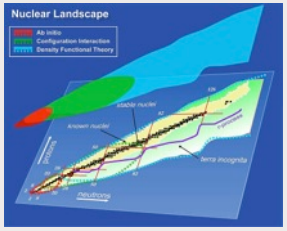
McGill University
McMaster University
University of Northern BC
University of Regina
Saint Mary's University
University of Winnipeg

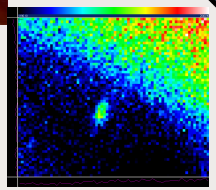
TRIUMF is owned & operated by a consortium of 18 universities
Founded 45 years ago in Vancouver

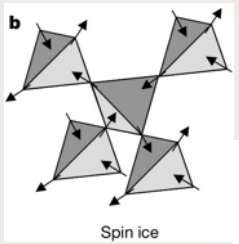
TRIUMF's Research Program & Vision

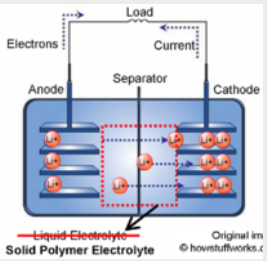


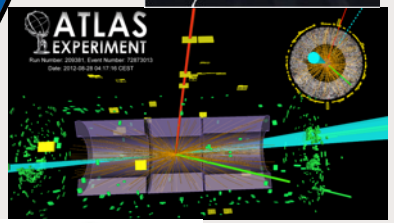












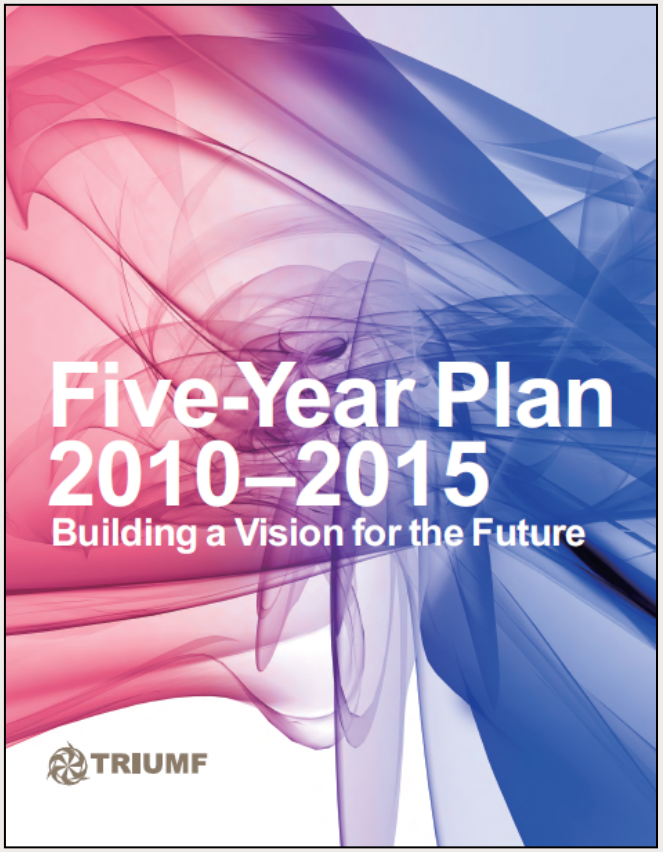
Delivering Five Year Plan 2010 - 2015

Five-Year Plan 2010-2015: On Track

NRC Contribution Agreement identifies deliverables:

- In Particle Physics, TRIUMF will …
  - ✓ Support Canadian efforts in T2K, ATLAS, ALPHA, PIENU
- In Nuclear Physics, TRIUMF will ….
  - ✓ Develop isotope beams from actinide targets
  - ✓ Complete IRIS
  - ✓ Complete EMMA
- In Nuclear Medicine, TRIUMF will …
  - ✓ Complete development of GMP labs
  - ✓ Produce medical isotopes for the PPRC and BCCA
- In Molecular and Materials Science, TRIUMF will …
  - ✓ Complete the M20 muon beamline
  - ✓ Complete the M9A muon beamline
- For ARIEL, TRIUMF will …
  - ✓ Complete civil construction of the ARIEL facility
  - ✓ Fabricate & assemble the Injector Cryomodule
  - ✓ Deliver electron beams at 25 MeV, 100 kW

Legend
- ✓ Completed
- ✓ In progress & on track
- ✓ Late completion



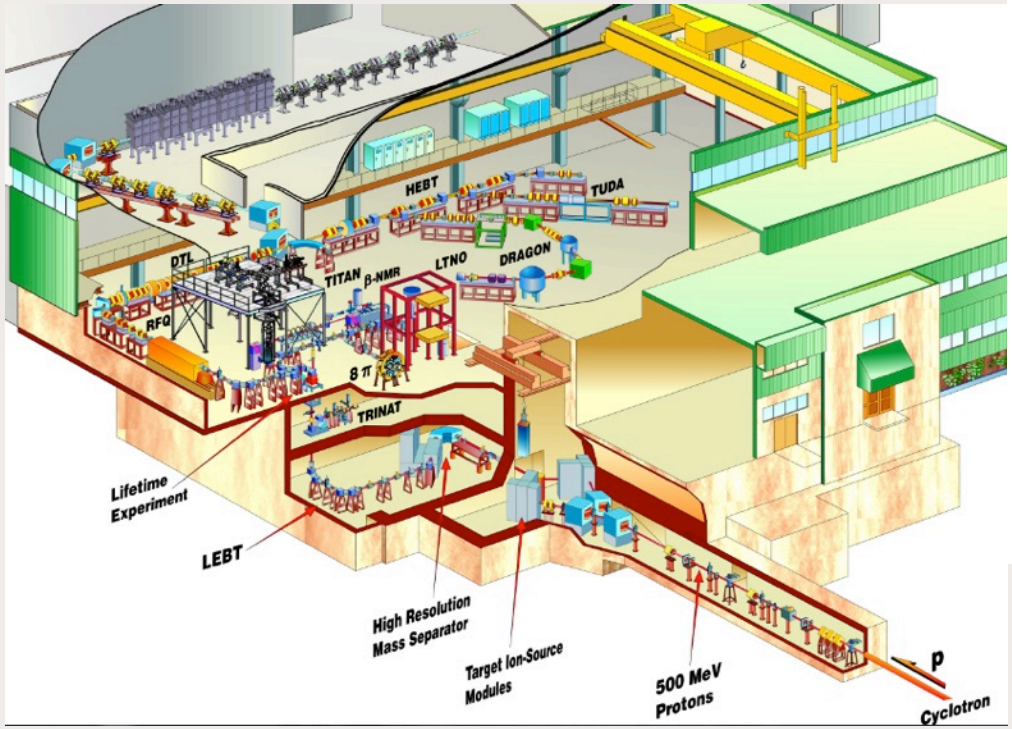
ISAC Rare Isotope Facility

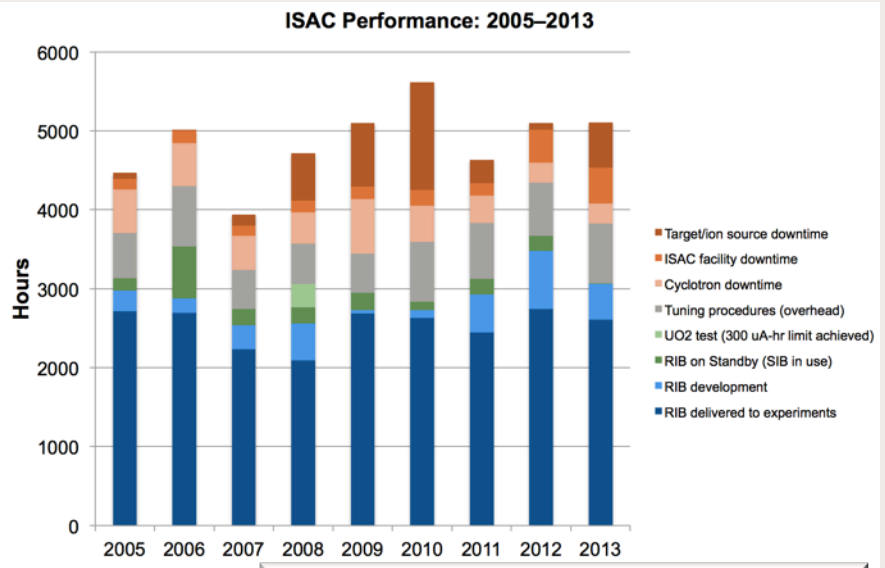
Operations and research highlights

ISAC Rare Isotope Program

ISOL facility with ***highest primary beam intensity*** (100 μA, 500 MeV, p)

ISAC I: 60 keV & 1.7 AMeV **ISAC II**: 5.8 - 16 AMeV (heavy – light)





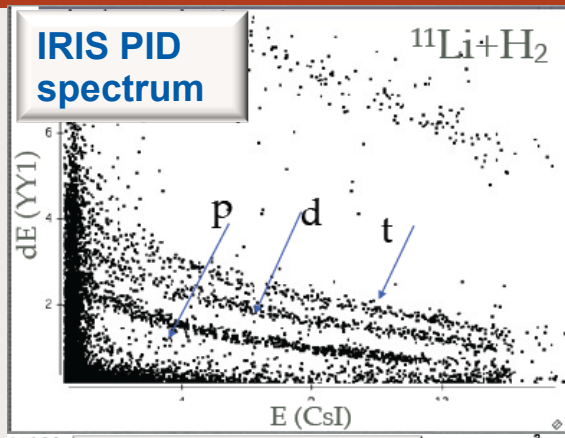
2013:
3064 hours RIB delivery
(73.5% of scheduled)
2607 hours experiment run time
457 hours development (15%)
759 hours procedural overhead

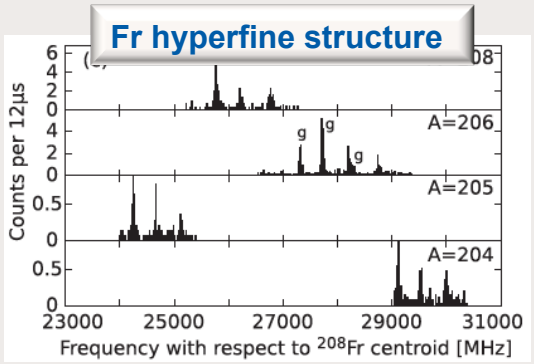
1 of 9 production target failed
(TM4 FEBIAD cooling coil water leak)

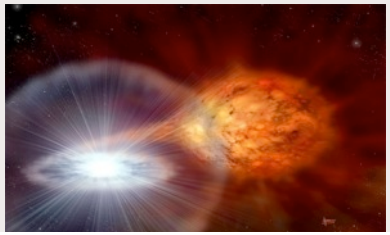
- Backlog ~2 years (required for operational needs)

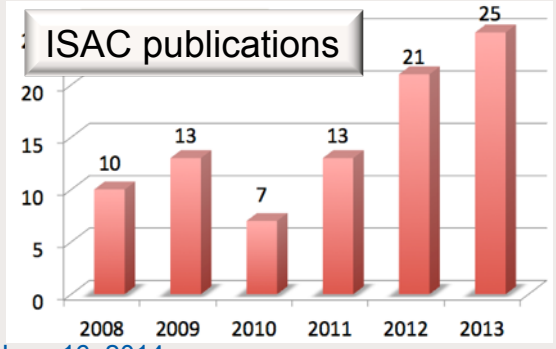
Selected Nuclear Physics Highlights

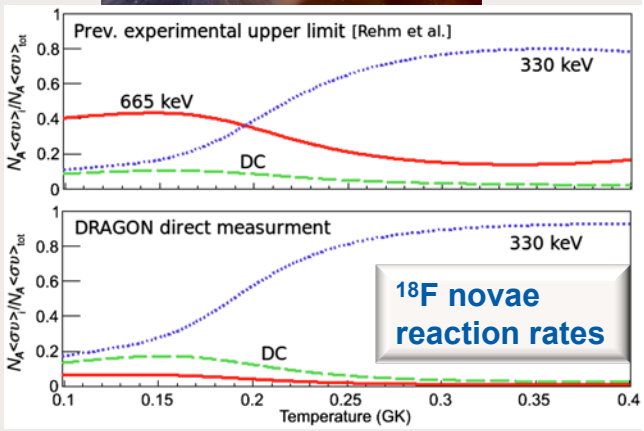
- Experimental program of **IRIS** solid-H target reaction facility started successfully (^{11}Li, ^{10}C, ^{12}Be)
- First physics experiment w/ **high-mass accelerated RIB** from charge state booster: d(^{94}Sr,p) w/ TIGRESS+SHARC
- Collinear **laser spectroscopy** of ^{204,205,206}Fr ➔ ground state spins, moments and changes in RMS charge radii [PRL]
- ^{18}F(p,γ) reaction in novae rate measured by **DRAGON** [PRL]

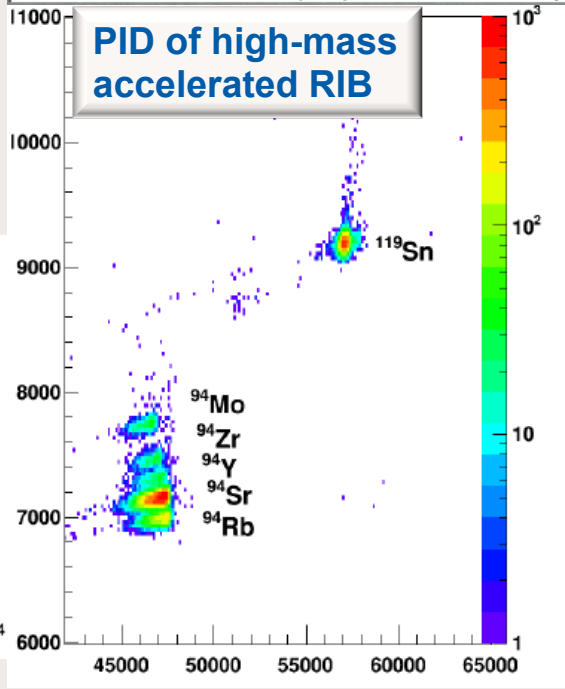






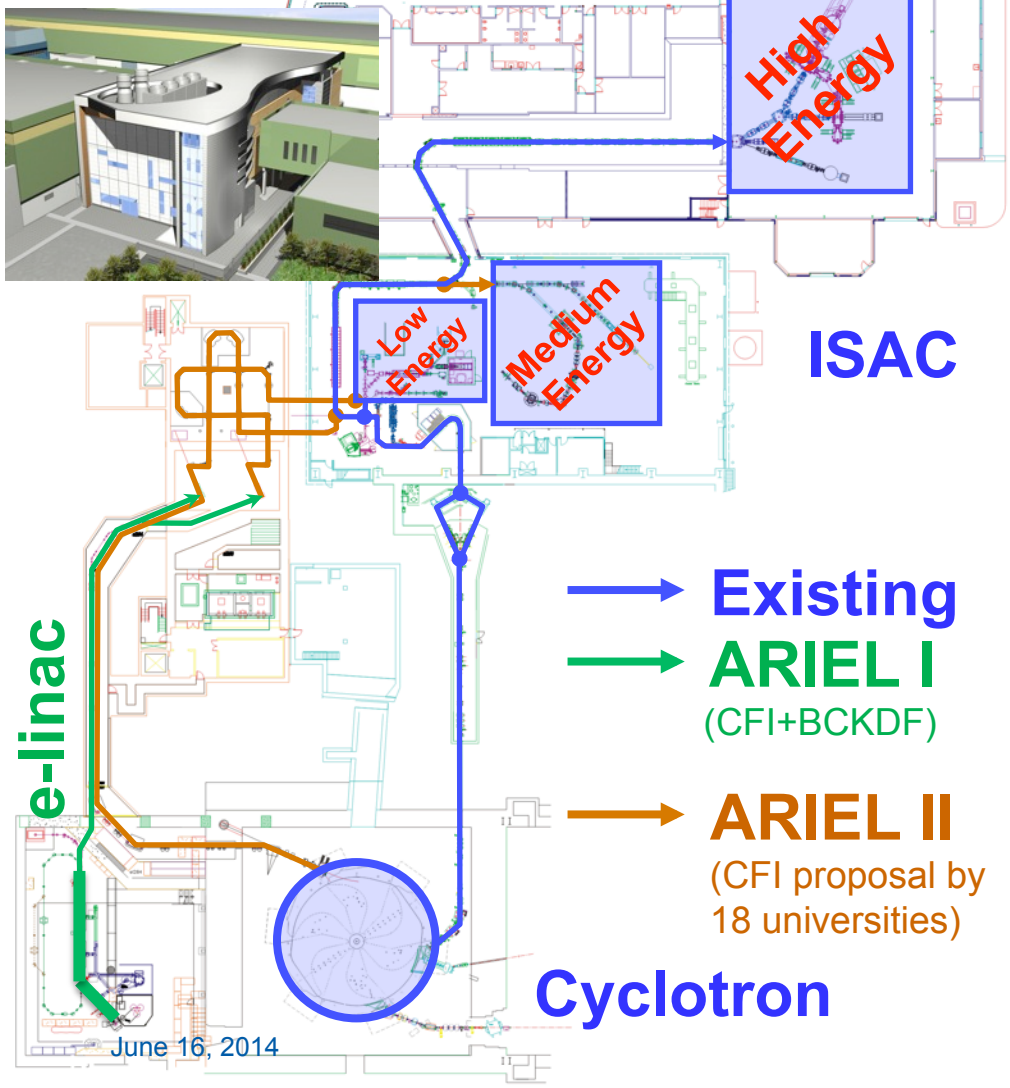






ARIEL Progress

Advanced Rare IsotopE Laboratory (ARIEL)



ARIEL is TRIUMF's flagship:
Isotopes for Science & Medicine

Substantially expands Canadian capabilities

- Three simultaneous RIB beams
- More "time" for science with world leading instrumentation
- More and new isotopes for
  - Nuclear Physics
  - Nuclear Astrophysics
  - Fundamental Symmetries
  - Materials Science
  - Nuclear Medicine
- More national & international users
- Phased implementation interleaving science with construction
- Compete with the best in the world

ARIEL Building Completion

ACEC-BC* Award of Merit, 2014 April 11

- **Culmination of 3 years work**
- **Meets needs of entire ARIEL scope**

*Association of Consulting Engineering Companies of BC.

e-Linac Progress

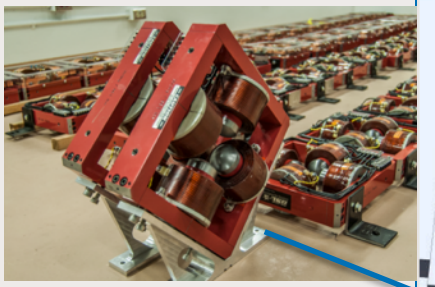
Klystrons

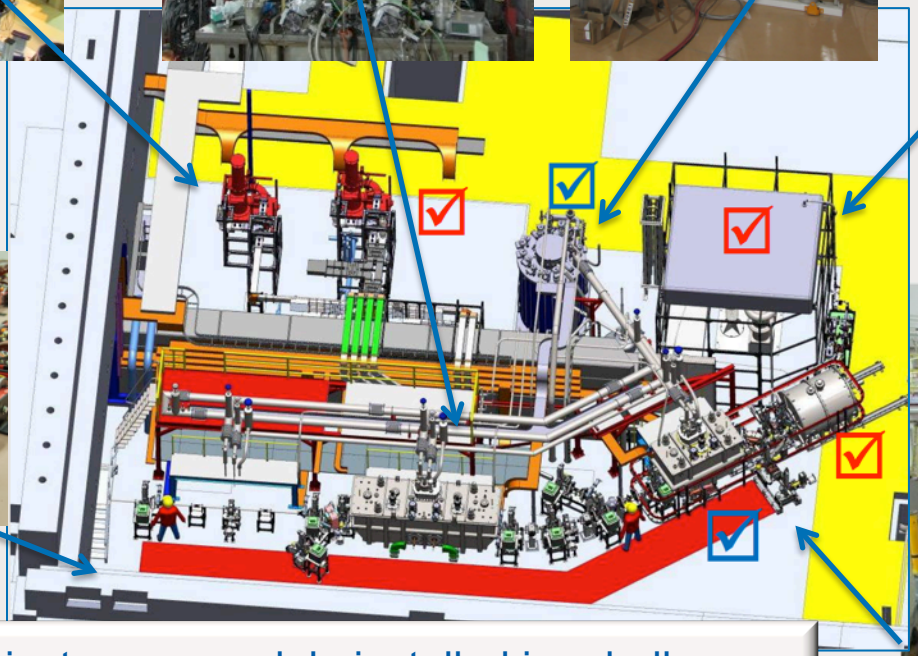
Cryogenics infrastructure

LHe cold box

e-Gun HV power supply

Beamline magnets





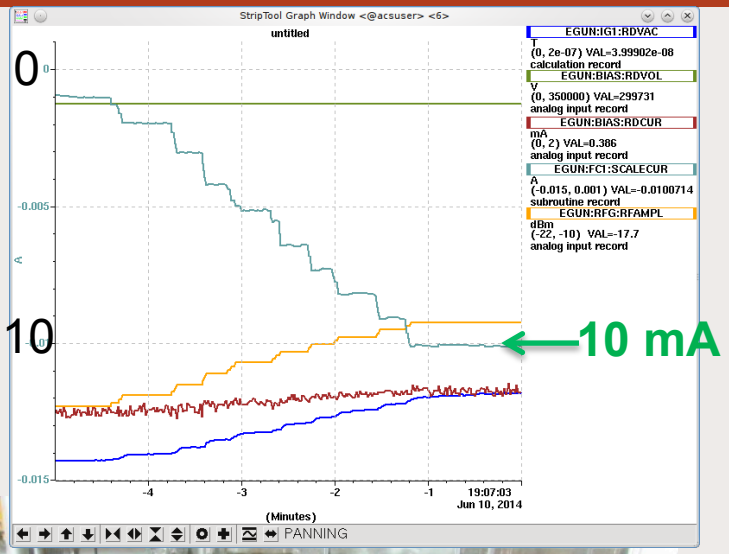
e-Gun and injector cryomodule

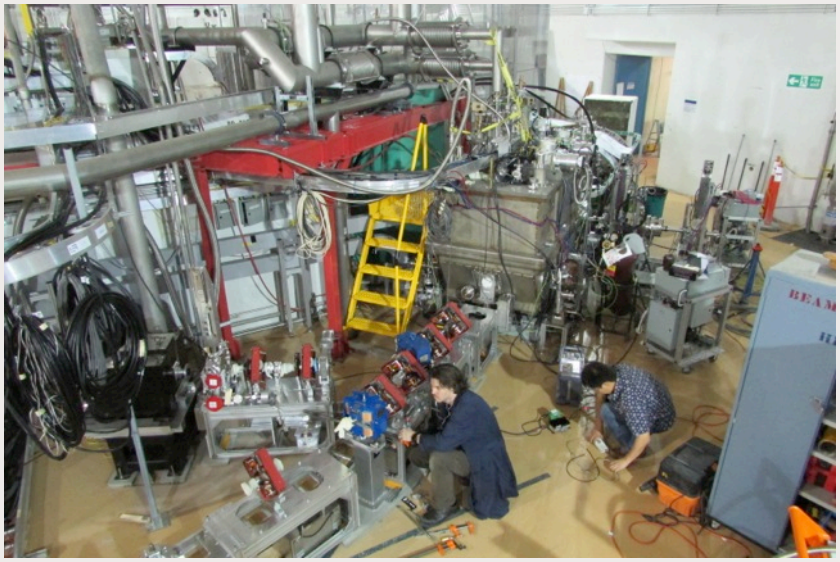
- E-gun and injector cryomodule installed in e-hall
- Commissioning started (CNSC license for 3kW)
- On track for fall delivery of 25MeV, 100kW beam

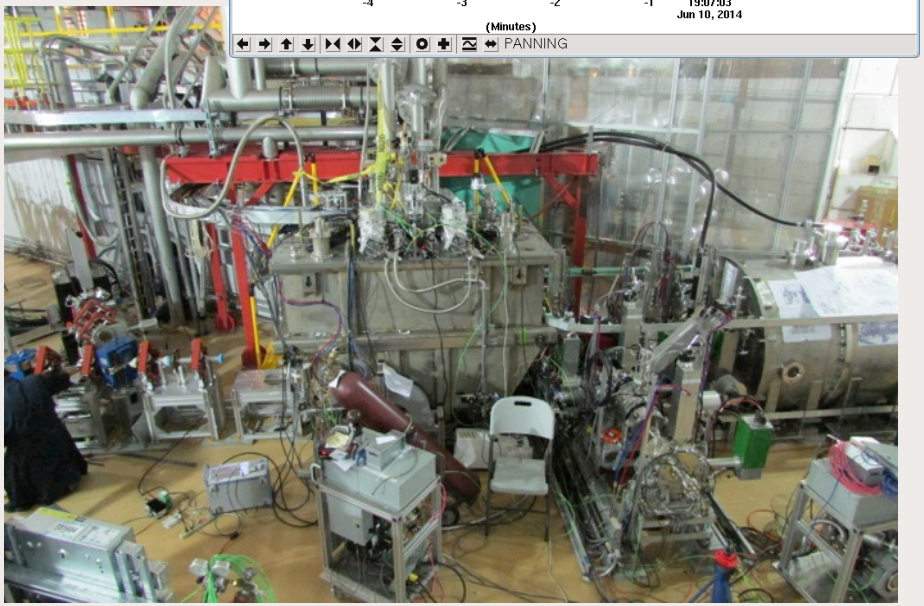
More on ARIEL:
ARIEL talk (R.K.)
W1-1, Wed. 9:00

ARIEL e-Linac: Installation & Commissioning Status

- Electron source operated at 300 kV, up to 10 mA peak current @ 1% duty factor
- 880 watts of CW RF power applied to injector cavity to test RF power transmission to power coupler
- Injector cavity cooled to 4K
- RF tests started on June 12







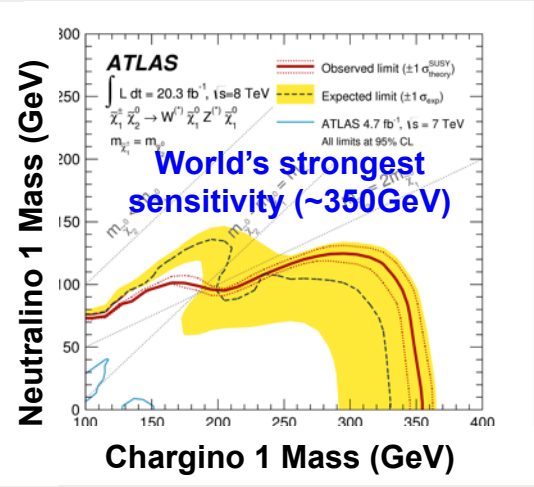
Particle Physics

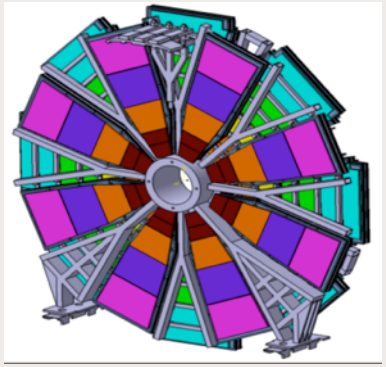
Research highlights

Upgrades and installations

ATLAS

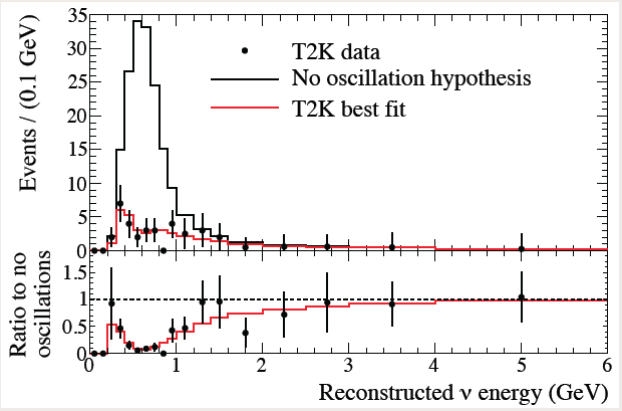
- **Leading involvement in data analysis efforts**
  - Higgs characterization, search for 'Natural SUSY', searches for high-mass resonances
- **maintaining leadership roles within ATLAS collaboration**
  - e.g. Savard Higgs convener, Canepa Upgrade Physics Group convener (10/14)
- **TRIUMF support for LS2 (2018) upgrades**:
  - New Small Wheel / small Thin Gap Chambers:
    - Laboratory space for cathode preparation and carbon/epoxy spray facility for resistive layer coating of the chamber interior walls
    - Technical, engineering, administrative support for upgrade project
  - High Precision Calorimeter Level-1 Trigger
    - Trigger board and base-plane upgrades for Hadronic End Cap / Forward Calorimeter
- **ATLAS Tier-1 data centre at TRIUMF**
  - Strong collaboration with HEPnet/Canada, CANARIE, Compute Canada
  - Smooth 24x7 operation at maximum capacity and reliability
  - Implementation of equipment refresh and expansion to keep track with needs of the science program
  - New satellite server room + tape expansion (FY2015)

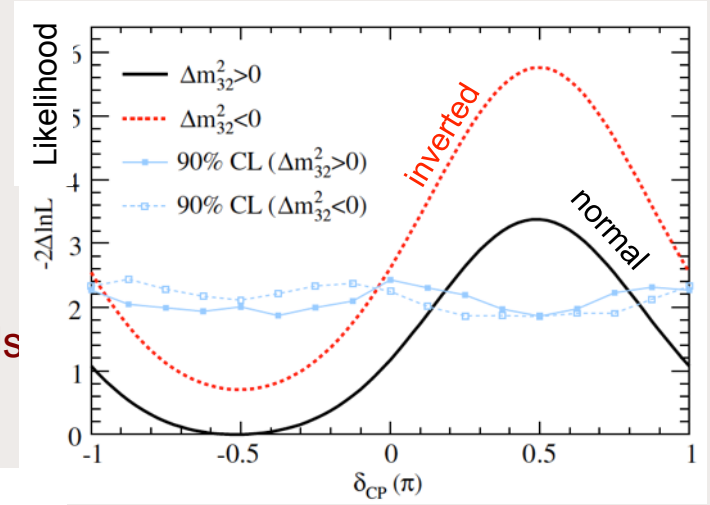




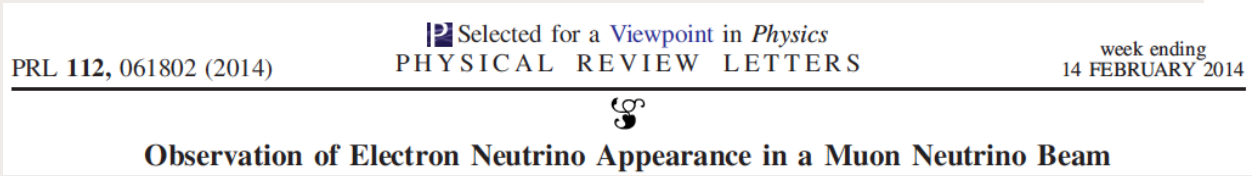
T2K / HyperK

- December 2013: Japanese **Suwa award** for T2K beam-line group, including Canadians from TRIUMF, Toronto, and York
- **J-PARC re-started operation** early 2014 after recovery from radiation incident in May 2013 in the hadron facility
- T2K data taking with **anti-neutrino beam** started late May
- Recent publication (PRL, Feb. 2014):
  - ν_e appearance paper with a significance of 7σ.
  - best precision in the mixing angle θ_{23} (maximal mixing)
  - 90% CL inclusion range
    [-1.17, 0.15]π for normal mass hierarchy
    [-0.91,-0.09]π for inverted mass hierarchy
    ➔ hinting towards CP phase around $-\pi/2$





- TRIUMF supports R&D activities and CFI proposal towards kiloton detector (nuPRISM - HyperK prototype)


Selected for a Viewpoint in *Physics*
PRL **112,** 061802 (2014) PHYSICAL REVIEW LETTERS week ending 14 FEBRUARY 2014

Observation of Electron Neutrino Appearance in a Muon Neutrino Beam

ALPHA

ALPHA-Canada was awarded the
2013 NSERC John C. Polanyi Award
for trapping and spectroscopy of antihydrogen atoms

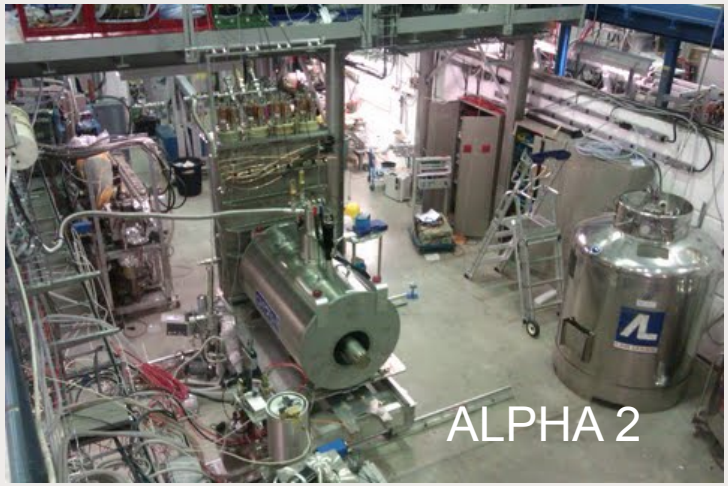
APLHA sets experimental limit of on antihydrogen charge

$$Q = (-1.3 \pm 1.1 \pm 0.4) \times 10^{-8}$$

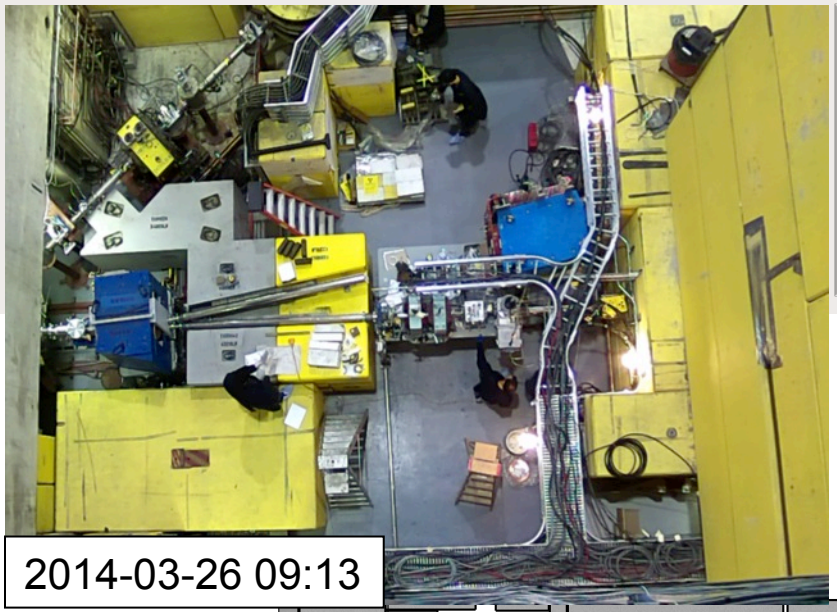
nature COMMUNICATIONS

Completion and commissioning of ALPHA-2

- very significant engineering and manufacturing contributions from TRIUMF and Calgary
- preparing for beam time at AD in August 2014



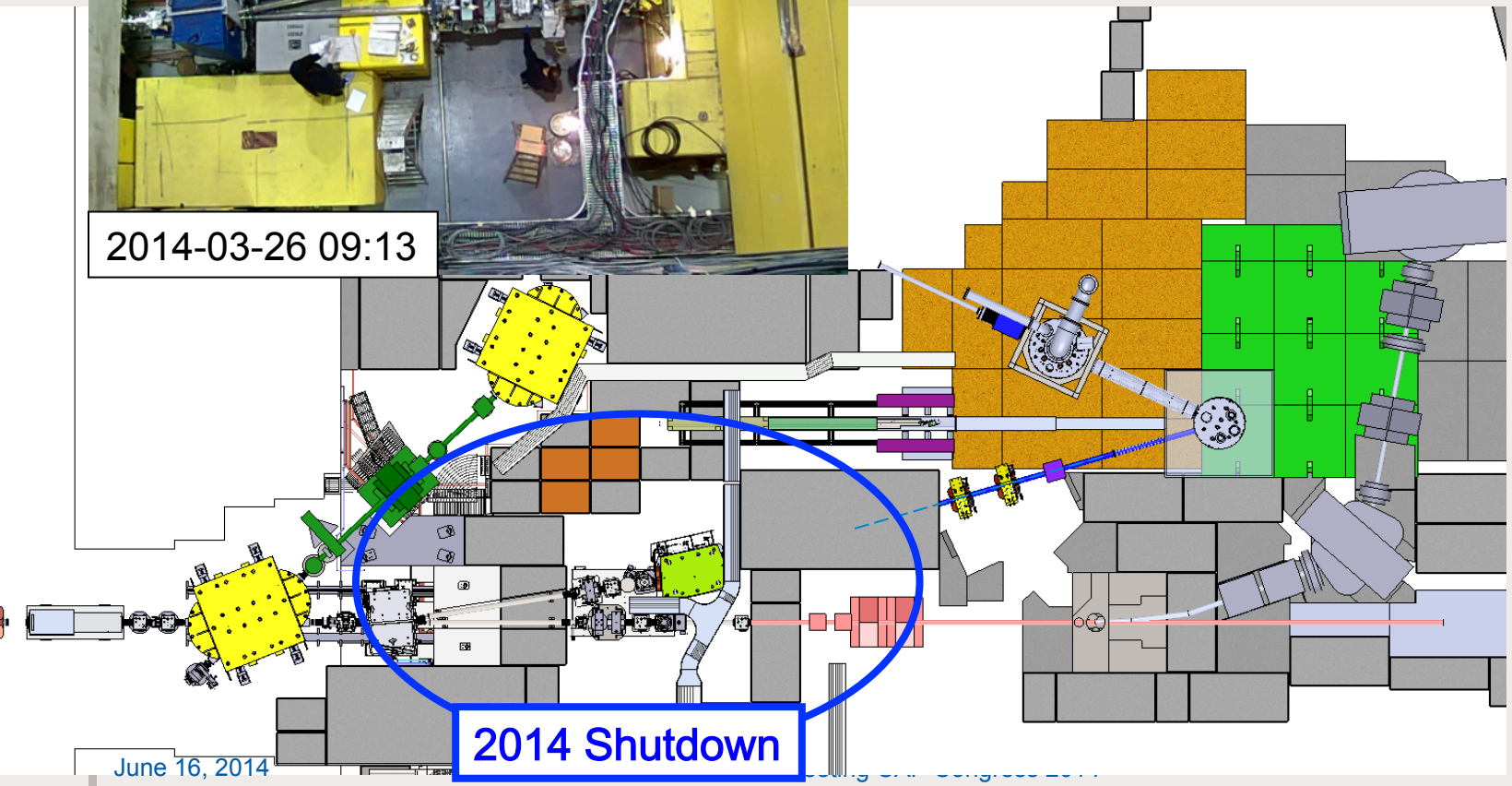
UCN Beamline Installation



UCN beamline, target and source installation to be completed by 2016 ➔ first Canadian UCN

Source development at RCNP Osaka

Competitive nEDM experiment by 2018



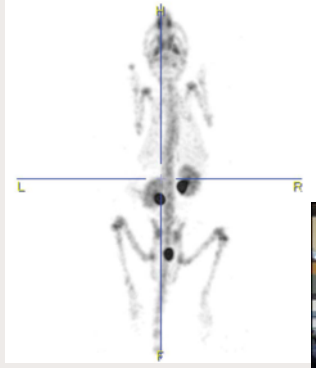
Nuclear Medicine

Accelerator based production of ^{99m}Tc

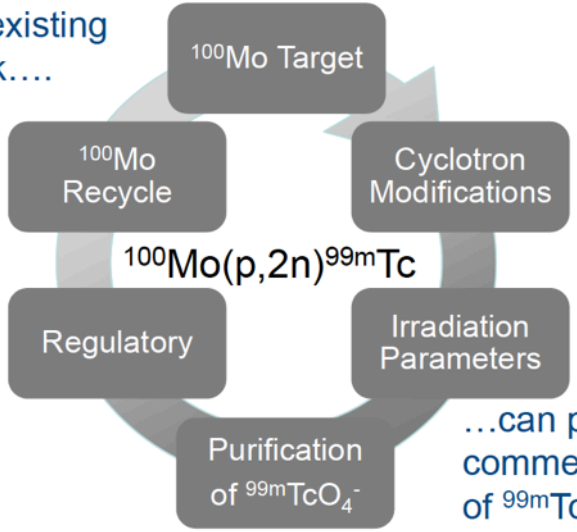
Institute for Accelerator Based Medical Isotopes

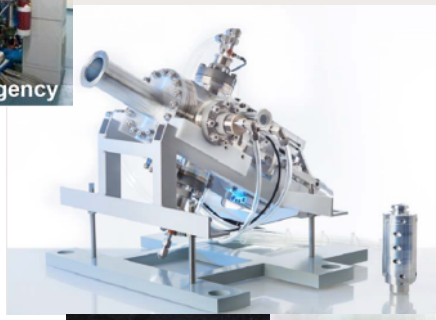
Accelerator Produced ^{99m}Tc

NRCan ITAP project (TRIUMF, BCCA, Lawson Health, CPDC)

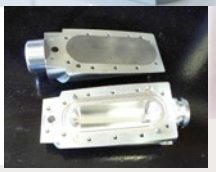


To demonstrate existing cyclotron network….





…can produce commercial quantities of ^{99m}Tc



- Full production cycle has been demonstrated
- Sufficient production for metropolitan area (e.g. Vancouver) demonstrated (ACSI TR-19 & GE PETtrace)

➔ validates business proposition that conventional cyclotrons around the world can be upgraded to produce Tc-99m for their respective region

- TRIUMF/AAPS spin-off company ARTMS^{TM} formed to supply ^{100}Mo-coated solid cyclotron targets

➔ from centralized generator production to local on demand production

Institute for Accelerator-based Medical Isotopes (IAMI)

May 30, 2014: The Honourable Michelle Rempel, Minister of State for Western Economic Diversification announced funding of $5.5 million to support TRIUMF in procuring a new TR-24 cyclotron and the development of the Institute for Accelerator-based Medical Isotopes (IAMI).

PPRC/GMP program
- Meet demand
- Enable new interests
- Added capacity for collaboration

Research program
- Target/Nucl. Chem
- Radiochemistry
- Applications

Commercial program
- ^{99m}Tc, ^{18}F
- PRC via CCM
- Added capacity

Training program
- CREATE (Kruecken)
- Courses
- Visitors

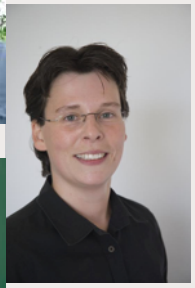
Innovation:
- Interface ISAC ISOL, ARIEL with Nuc. Med. community
- Radiotherapeutic isotopes

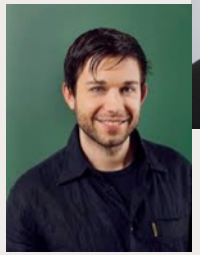
courtesy Paul Schaffer

Other News

Recent hires (since last CAP congress)

- Mark Hartz (IMPU Tokyo/TRIUMF) – T2K/HyperK
- Iris Dillmann – Nuclear Astrophysics
- Jason Holt – Nuclear Theory





TRIUMF becomes Institutional Member of the Royal Society of Canada

RSC
The Royal Society of Canada
The Academies of Arts, Humanities and Sciences of Canada

SRC
La Société royale du Canada
Les Académies des arts, des lettres et des sciences du Canada

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NSERC CREATE program Isotopes for Science and Medicine funded at UBC/TRIUMF

Training program in isotope related science – Nuclear Physics, Nuclear Chemistry, Nuclear Medicine, Materials Science, Earth & Ocean Science

IsoSiM

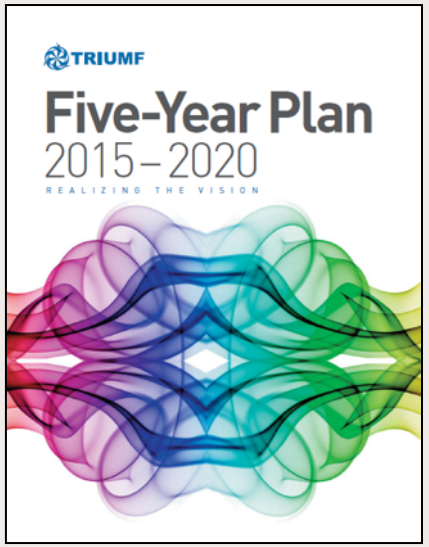
www.isosim.ubc.ca

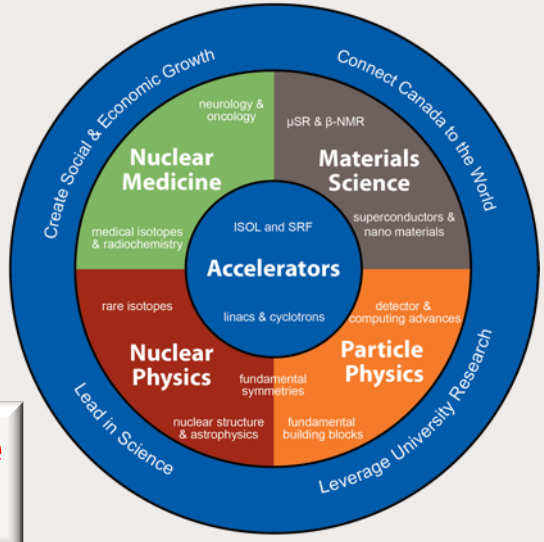
Outlook towards 2020

Five-Year Plan 2015-2020

5YP 2015-2020 fulfills on the decadal vision pursuing **3 OVERARCHING GOALS:**

- **Sustain Canadian excellence in particle & nuclear physics**
- **Advance Canadian mastery of science, technology, and business of isotopes for science & medicine**
- **Revitalize TRIUMF's core infrastructure and secure its role in attracting & retaining talent**





Level of achievement is set by core operating funds provided via NRC Contribution Agreement

Thanks to all members of the community that have contributed and provided guidance & feedback !!

Supporting Elements

1. Be at the global forefronts of rare-isotope beam science.
2. Complete ARIEL and tap its unique capabilities for isotope production.
3. Pursue promising discoveries in next generation of global particle-physics experiments.
4. Convert the progress and potential of nuclear medicine into a regional centre of excellence.
5. Expand international use of TRIUMF's particle probes for materials characterization.
6. Expand Canada's position as a world leader in accelerator science and technology.
7. Work with AAPS to identify, apply, and deliver technologies that address market needs.
8. Renew key infrastructure & capabilities to retain top talent (and secure the next 40 years!).

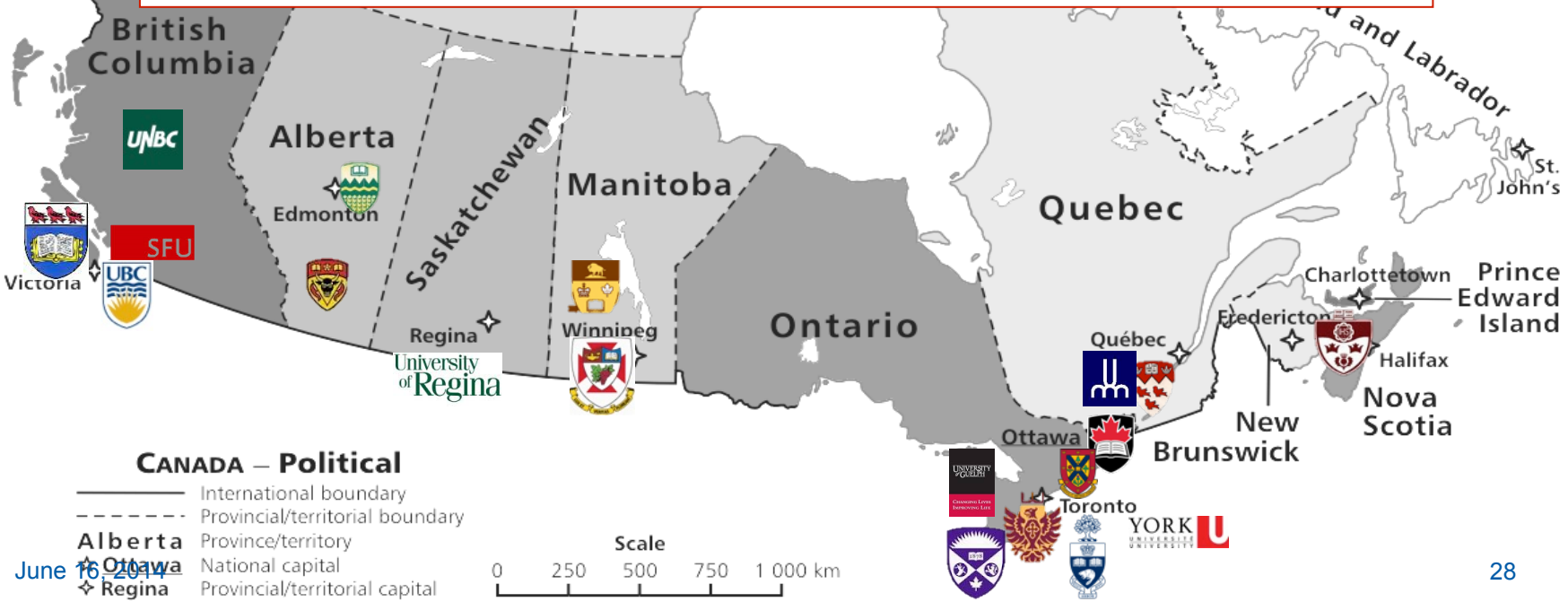
5YP 2015-2020: ARIEL-II

- Completion of ARIEL offers Canada "first-mover" advantage in globally competitive field of rare isotopes
  - TRIUMF will lead the world with multiple beams & multiple production techniques
  - Competition is fierce and Canada has a head start

- Completion of ARIEL (ARIEL-II) is being led by UVic & will be submitted to CFI "Innovation Fund 2015"
  - 19 universities participating (one non-member)
  - $32.4M total project cost

ARIEL- II Participating Universities and Principal Users

Name	Institution	Department
Karlen, Dean	University of Victoria	Physics and Astronomy
Buchinger, Fritz	McGill University	Department of Physics
Chow, Kim	University of Alberta	Department of Physics
Garrett, Paul	University of Guelph	Physics
Gwinner, Gerald	University of Manitoba	Physics & Astronomy
Kanungo, Rituparna	Saint Mary's University	Astronomy and Physics
Merminga, Lia	TRIUMF	Accelerator Division
Orr, Robert	University of Toronto	Physics
Prato, Frank	St. Joseph's Health Care London	Lawson Imaging
Schaffer, Paul	TRIUMF	Nuclear Medicine

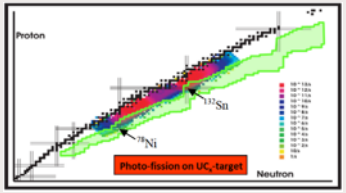


ARIEL Timeline

June 2010
ARIEL Project begins

August 2013
ARIEL Building complete

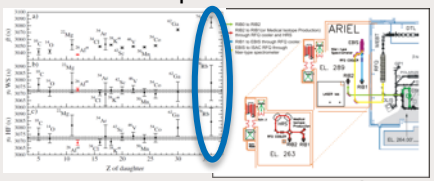
September, 2014
e-linac Phase 1 Complete

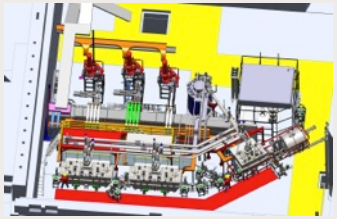


ARIEL-II Phase 2
Photofission ➔ r-process

March 2015
ARIEL-II CFI decision

ARIEL-II Phase 3 (CANREB)
Pure High Mass accel. RIBs
Medical isotopes collection station



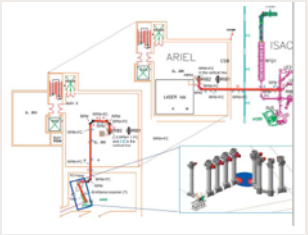


ARIEL-II Phase 5
Extend r-process reach

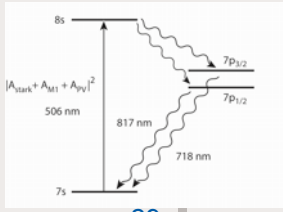
2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020

August 2013
TRIUMF-VECC MOU Add-3 signed

ARIEL-II Phase 1
Materials Science at β-NMR



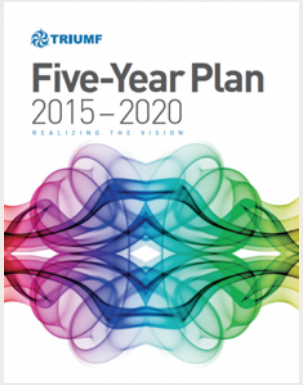
ARIEL-II Phase 4 (BL4N)
Fundamental Symmetries
Two ARIEL beams



SAP Science Priorities in 5YR Plan 2015-20

The 5-Year Plan allows to realize the vision for

- a forefront **rare isotope science program** with ISAC and ARIEL
  - Nuclear Structure, Nuclear Astrophysics, Fundamental Symmetries
- continued leading involvement in **international particle physics** projects and breakthrough discoveries
  - top priorities: ATLAS, T2K, ALPHA
  - important involvement: DEAP, nEXO
- building the vision of the **Electric Dipole Moment Lab**
  - neutron (UCN/nEDM), atom (RnEDM), and evtl. electron (FrEMD)
- elevating Canada's leadership in **accelerator science** through world-leading user program and strong accelerator research and education



Detector CFI Proposals 2014 w/ TRIUMF

Project	Institutions
ALPHA-gravity	**Calgary**, SFU, UBC, York
ATLAS NSW + LAr	**Carleton**, SFU, McGill, Montreal, UVic,
GRIFFIN-shields	**Guelph**, SFU
PINGU	**Alberta**
T2K / HyperK	**UBC**, Regina, York
UCN - nEDM	**UBC**, Manitoba, UNBC, Winnipeg

> $21M of CFI funds requested

- Projects responded to TRIUMF call for information on CFI proposals
- TRIUMF Gate 1 reviews were carried out for all proposals (+ university selection proc.)
- Follow-up with status reviews to firm up project plans and requests of TRIUMF resources

International Peer Review – Nov. 13 – 15, 2013

Overarching finding:

The IPRC found TRIUMF's research activities during the period 2010-2015 to be world class and meeting or exceeding the expectations of TRIUMF's plan for that period.

Recommendation:

The IPRC unanimously endorses the goals of the 2015-2020 5-Year Plan and recommends fully funding TRIUMF's request.

Dr. Samuel Aronson (BNL) (chair)
Dr. Juha Äystö (Helsinki IPP)
Ms. Frenny Bawa (Nanotech Security Corp)
Dr. Silvia Jurisson (Missouri)
Dr. Barbara Jones (IBM Almaden)
Dr. Robert McGreevy (ISIS RAL)
Dr. Hugh Montgomery (JLAB)
Dr. Jerry A. Nolen (ANL)
Dr. Maury Tigner (Cornell)

NRC Evaluation - 2013

"Overall, the findings of the evaluation of NRC's contribution to TRIUMF show that the activities undertaken by TRIUMF represent good value-for-money for NRC and for Canada. The implementation of the recommendations will be important to enable TRIUMF to continue to perform at a very high level, yield greater impacts from their commercialization activities and ultimately support the priorities of the research community in subatomic physics research and Canada's S&T strategy."

Final Evaluation Report of NRC's Contribution to TRIUMF March 27, 2014

Budget Situation

- Budget 2014 announced $222M commitment to TRIUMF through NRC
  - early announcement of core funding is pioneering---and **very welcome**
  - budget certainty provides competitive advantage and planning stability

➔ secures continued excellence in key areas of particle and nuclear physics

- TRIUMF's case for increased operating funds is recognized in Ottawa

- TRIUMF is working to identify and secure additional funding to
  - seize the moment in rare isotope research, being first on key measurements;
  - enhance applied research areas of nuclear medicine and materials science;
  - increase opportunities for commercialization & technology transfer.

Conclusion

- TRIUMF is performing well and is recognized for its successes in basic science, medical isotope production, and commercialization
- Success is result of close link to community in all program aspects
- Completion of ARIEL is the flagship project for the laboratory for the next Five Year Plan.
- International engagement in major science endeavors remains a priority
- TRIUMF is working to secure additional funding to deliver ambitious plan
  - ARIEL-II CFI will seek equipment funding, TRIUMF will provide manpower
  - Detector CFI proposals will provide critical project funding
  - Other competitive opportunities will be pursued as they present themselves
- TRIUMF will work with the community during the 5YP implementation

Thank you!

Merci!

TRIUMF:
Alberta | British Columbia | Calgary | Carleton | Guelph | Manitoba | McMaster | McGill | Montréal | Northern British Columbia | Queen's | Regina | Saint Mary's | Simon Fraser | Toronto | Victoria | Winnipeg | York

Owned and operated as a joint venture by a consortium of Canadian universities via a contribution through the National Research Council Canada
Propriété d'un consortium d'universités canadiennes, géré en co-entreprise à partir d'une contribution administrée par le Conseil national de recherches Canada

UBC/TRIUMF NSERC CREATE program: Isotopes for Science and Medicine

- Training program to provide students with unique skills required to be employed in isotope related fields, to develop new radioisotopes, and to promote innovation of new isotope applications.
- Involved sub-fields:

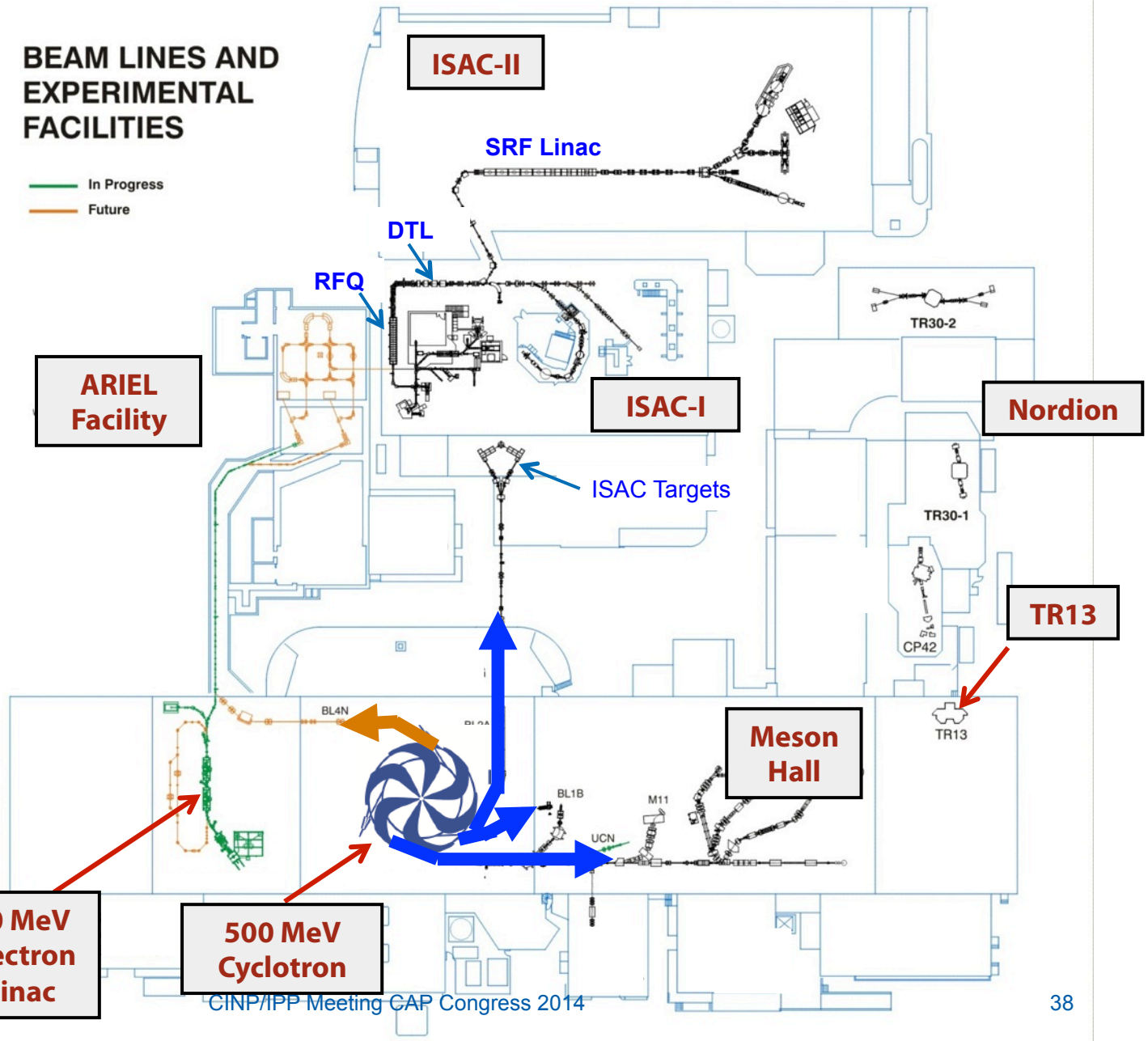
Ocean Science	Medical Applications	Pharmaceutical Sciences
Material Science	Nuclear Physics	Accelerator Science

- 3-6 months International Research Experience at German partner institutes: **Helmholtz, Max-Planck, Siemens-Foundation, GE Research Centre Munich**
- Teaching concept
  - 4th year undergraduate course on "Use of Isotopes in Science and Medicine"
  - Modular interdisciplinary graduate level lecture series individually tailored to complement respective sub-field lectures
  - Graduate level lab. course to gain hands-on experience in all isotope related research
- Industrial internships (AAPS, ACSI, PAVAC, Nordion, Lorax, etc.)

➔ Fully funded ($1.65M over 6 years), PI: R. Kruecken

TRIUMF Accelerators

- 500MeV H^- cyclotron since 1974
- Only ISOL facility in North America
- Highest power Isotope Separation On-Line (ISOL) facility worldwide
- Only ISOL with > 5 MeV/u accelerated beams
- Adding 50MeV 500kW e-Linac



International Peer Review & NRC evaluation

IPR Committee members:

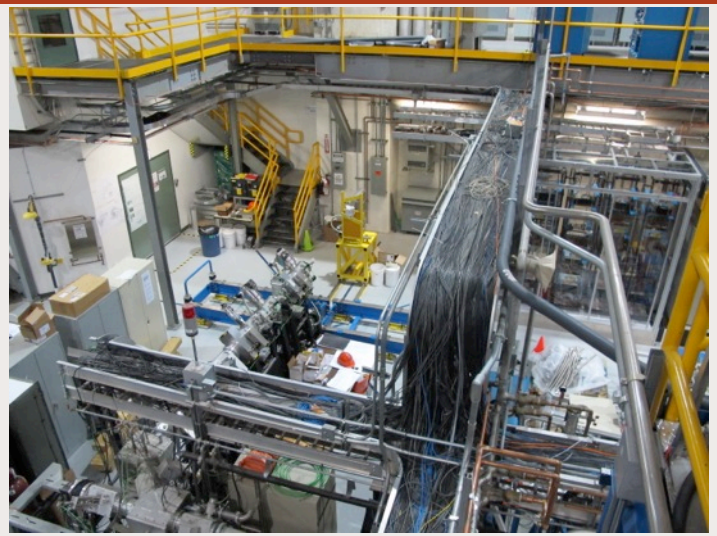
Dr. Samuel Aronson (BNL) (chair)
Dr. Juha Äystö (Helsinki IPP)
Ms. Frenny Bawa (Nanotech Security Corp)
Dr. Silvia Jurisson (Missouri)
Dr. Barbara Jones (IBM Almaden)
Dr. Robert McGreevy (ISIS RAL)
Dr. Hugh Montgomery (JLAB)
Dr. Jerry A. Nolen (ANL)
Dr. Maury Tigner (Cornell)

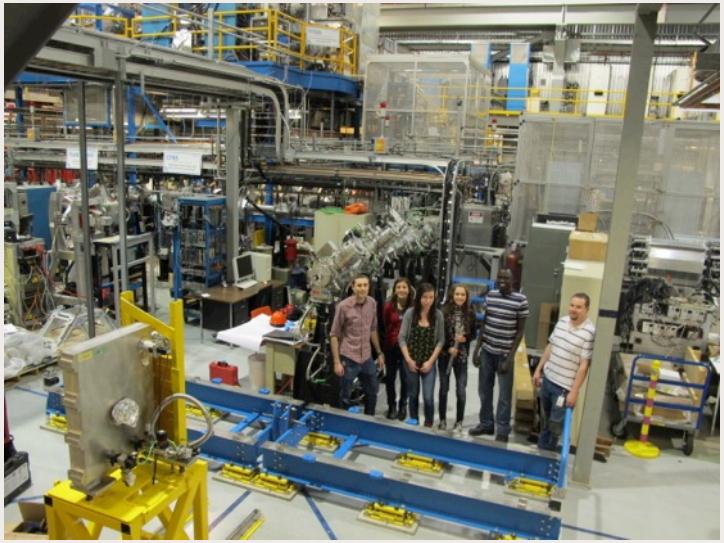
- The IPRC was impressed by TRIUMF's world class research activities and achievements during the period 2010-2015.
- The IPRC commended TRIUMF for its educational efforts and the strong connection to the Canadian universities
- The IPRC supported the ambitious goals of 5YP 2015-2020 and the associated requested funding level.

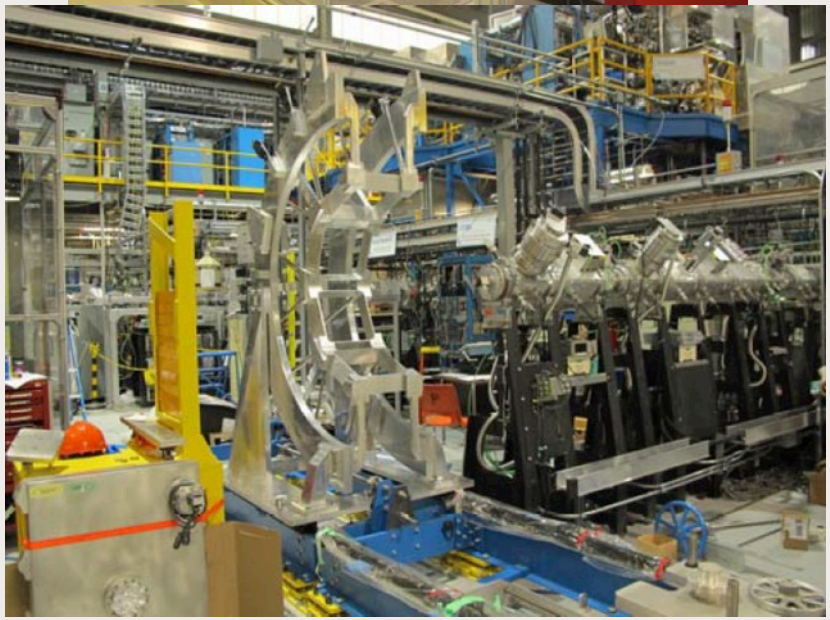
IPR was one line of evidence in NRC evaluation

➔ NRC evaluation report, including IPRC report, to become public shortly

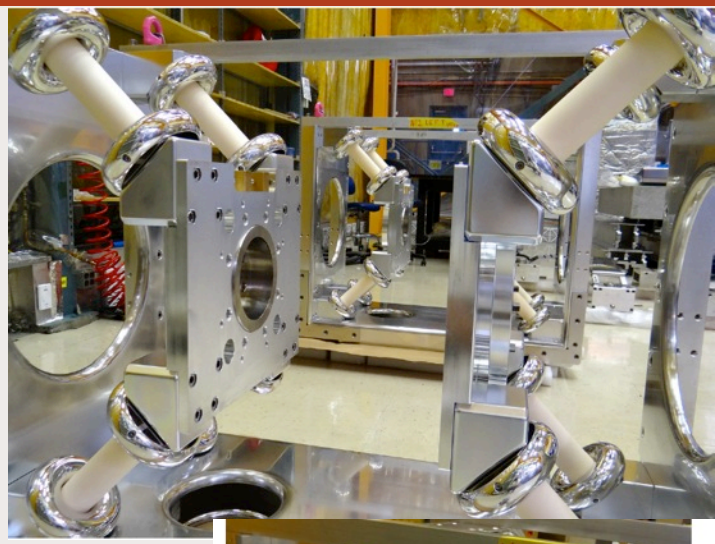
GRIFFIN installation on track







EMMA installation delayed



- ED tanks Pb shielding installed, positioned
- plumbing and electrical services being installed
- ED insulators broken in factory or during transport
  ➔ redesigned insulators ➔ $100K replacement
- in-beam test of PGAC FP detector performed successfully
  ➔ completions of EMMA in 2015